# Assessment of Heavy Metal Contaminants in Local Cassava Chips Associated with Vehicular Traffic in Makurdi Metropolis, an Agrarian City

[1, 2]Tyohemba, L. Raymond, [1]Akpoghol, V. Timothy, [1]Kiragu Denis, [3]Otanwa, E. Helen, [1]Igwe, Vivian & [1]Tyav, Simon.

[1]Department of Chemistry, Benue State University, Makurdi
[2]Centre for Food Technology and Research, Benue State University, Makurdi
[3]Department of Chemistry, Federal University of Health Science, Otukpo
: rtyohemba@bsum.edu.ng; +(234) 7037735706

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***Abstract:***
**In the present study, we investigated the levels of lead (Pb), copper (Cu), cadmium (Cd), and chromium (Cr) using cassava chips dried by select road junctions as an indicator for heavy metals associated with automobile emissions in Makurdi Metropolis. Fresh cassava tubers were obtained and processed like the locals' producing cassava chips, which were sun-dried at the selected junctions. Metal analysis was carried out using Microwave Plasma Atomic Emission Spectroscopy (Agilent 4210 MP-AES). The analysis revealed varying concentrations of heavy metals at road junctions. Lead concentrations ranged from 1.26 mgkg$^{-1}$ to 5.18 mgkg$^{-1}$, exceeding safe limits set by WHO and NAFDAC. The levels of Cadmium in cassava chips exposed at some Junctions were also found to be above the maximum permissible levels set by local regulatory agencies. Copper concentrations ranged from 2.50 mgkg$^{-1}$ to 2.78 mgkg$^{-1}$, falling within permissible limits but varied across sampling points. Chromium concentrations 0.001 mgkg$^{-1}$ to 0.245 mgkg$^{-1}$. No permissible limit was found for chromium concentration from the local regulatory authorities. The findings highlight the significant contribution of vehicular emissions to environmental metal pollution in the studied area. Therefore, consuming cassava chips dried at these Junctions poses risks of toxic metals poisoning. Public awareness campaigns on the dangers of heavy metal exposure and the promotion of alternative drying methods for agricultural produce are recommended to safeguard public health.**

***Keywords:*** **Cassava chips, vehicular emissions, heavy metals, traffic, permissible limits, toxicity.**

## I. Introduction

*Manihot esculenta*, or cassava, is one of the three main tropical crops grown worldwide and is extensively grown in tropical and subtropical areas [1]. Cassava is the most important economic crop in Nigeria with the main use as a staple food. It is estimated that 70% in every ten Nigerians consume at least one cassava product daily. It is processed into different products such as cassava flakes commonly known as garri, cassava chips (lafun) and cassava paste (fufu) among others. Wet foods especially cassava chips or chips are always dried to prolong shelf life and reduce microbial attacks.

It is a widely acceptable energy food source to over 600 million consumers of cassava across the globe with relatively higher energy yield per hectare [71 tonnes/ha] [2]. The potential to appeal directly to farmers and indirectly to consumers was significant. Cassava-derived products, such as paste and flakes, are transformed into solid meals using hot water, typically accompanied by various soups (e.g., vegetable-based or draw soups) [3]. While the root is prized for its high carbohydrate content, the leaves also serve as valuable soup ingredients, particularly favoured by inhabitants of Nigeria's southwestern and southeastern regions [4].

Farmers apply various methods of drying ranging from the commonly used sun drying to modern technologies such as oven drying and irradiation. This allows the prolonged shelf life of the cassava chips and reduced microbial spoilage. The process leads to significant weight and volume reduction to ease packaging, storage and transportation space and costs. Sun drying is the most commonly used method by people in developing economies and small-scale farmers. Oven drying offers better quality control and the adjustments of the drying conditions such as duration, temperature and humidity over conventional sun drying though the former is expensive [5].

In Nigeria, sun drying is a widely used preservation technique for various food items such as grains and cereals, chips, spices, meats, cereals beans, vegetables among other agricultural produce. The process utilizes various surfaces such as concrete floors, propylene and woven mats, banana leaves, sacks knitted together and sometimes directly on the ground [6]. The drying duration typically takes 3-5 days depending on varying features. These include environmental conditions, the specific characteristics of the food being dried as well as atmospheric variables like temperature, humidity levels, and wind speed. This method thus plays a significant role in both the economic and nutritional aspects of many Nigerian households with the dried products used for household consumption or for sale.

The production of cassava flour involves several processing steps, including open-air drying, which frequently occurs along major highways to maximize sun exposure. This technique involves spreading fresh cassava chips on cement surfaces and periodically rotating them with shovels or rakes [7]. However, the proximity to high-volume traffic raises concerns about potential contamination from vehicle exhaust emissions. These harmful chemicals can infiltrate the cassava products, eventually entering the food chain and posing health risks to consumers [8]. Environmental pollution is a well-known pathway for heavy metals to contaminate crops and food supplies [9]. Factors such as traffic density, congestion patterns, duration of traffic delays, prevalence of roadside mechanics and vulcanizers, and proximity to highways, industrial areas, and workshops can significantly influence the concentration of toxic metals in the atmosphere [10].

Vehicular emissions may often contain potential toxic elements (PTEs) such as lead, copper, cadmium and chromium which are released from the vehicle exhaust, brake dust, tire ware and other parts. The emissions do not diffuse well such as in the case of chimney emissions since they are emitted close to the ground level hence easily settle on food dried near the roads [11]. Dust generated during the operation of vehicles is derived from a number of sources, such as wearing of breaking systems, tires and clutch plates, erosion of the active layer of the catalytic converter, or resuspension of road dust [12]. It has been shown also that in the cities where much braking is involved lead wearing out the brake pads contributes significantly to the amount of heavy metal pollutants of road dust [12].

Cassava flour, a common food staple in Makurdi City, Nigeria is susceptible to contamination when exposed to pollutants from vehicular traffic during roadside drying processes. Roadside drying of cassava chips in Makurdi Metropolis involves spreading the product on open surfaces near roads, where it can be exposed to emission and particulate matter generated by vehicles. The metropolis is characterized by high traffic, old roads and old vehicles. The concern arises from the potential for these toxic heavy metals to accumulate in the cassava flour over time and cause consumer health havocs. In this research, heavy metal (cadmium, chromium, lead and copper) deposits in cassava chips dried by four heavy traffic junctions in Makurdi Metropolis which have been linked to cancer and have the potential to harm the nervous system, heart, lungs, and other essential organs [13] were assessed using Microwave Plasma Atomic Emission Spectroscopy.

## II. METHODOLOGY

### I. SAMPLE COLLECTION AND PREPARATION

About seven (7) tubers of fresh cassava were sourced from a local farm in Makurdi, peeled and washed thoroughly with distilled water to remove impurities. The tubers were cut into smaller pieces and soaked in water for 3 days for it to soften after which it was mashed and put into 4 plastic trays labelled A, B, C and D to be dried in 4 different locations; A (Balcony Junction), B (Yina Junction), C (International Market Junction) and D (Terwase Agbadu/Nyon Junction) all on same axis/ along same road.

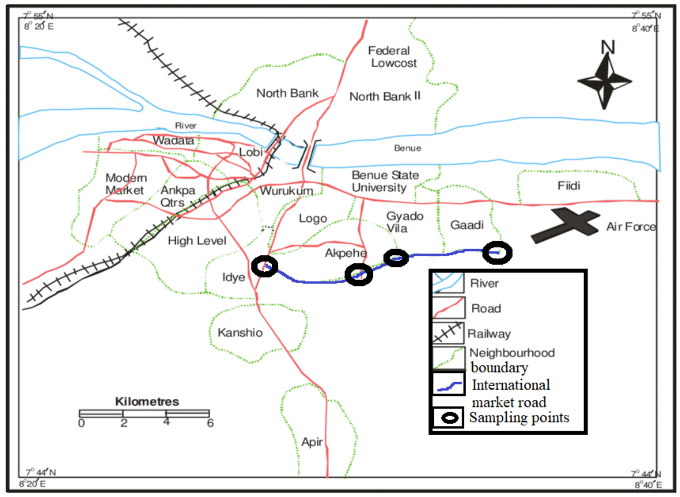


Fig. 1 Makurdi Metropolis map showing Sampling points

About 10 kg of the mashed cassava was separated and dried at home to serve as a control. The samples were dried from 6 am to 6 pm daily and small amounts were removed daily from each try and label as A1, B1, C1 and so on for samples A, B, C etc respectively for day 1 and then subsequently for the other days. This was done for seven (7) days of drying to give a total of 29 samples (i. e. including the control) collected. The samples were homogenized into powder using mortars and pestle. They were then sieved with 1 mm mesh into small zip lock bags labelled accordingly as well as the control which was ready for further treatment.

### II. SAMPLE DIGESTION

Crucibles were used for the digestion process. Exactly 5.0 g of the individual samples were measured into the crucibles and ashed in muffle furnace at a temperature of 450 ºC for 1 hr. After which the ash was removed from the furnace and kept in a desiccator for 20 mins to cool before extraction. In the crucibles containing ash, 5 mL of diluted nitric acid was measured and added into the ashes in the crucibles and stirred properly. The solution of ash and nitric acid was then filtered using Whatmann No. 1 filter paper. Distilled water was used to make up the volume of the filtrate to 25 mL and transferred into sample bottles for analysis.

### III. INSTRUMENTAL ANALYSIS

Metal analysis was carried out using Microwave Plasma Atomic Emission Spectroscopy (Agilent 4210 MP-AES) equipped with a standard sample introduction setup consisting of a OneNeb Series 2 Nebulizer and a double pass spray chamber was used for the total determination of the metals. An Autosampler was used to deliver samples to the instrument, allowing the system to be operated unattended. The instrument conditions for sample analysis are listed in Table 1 below.

Table 1 Instrument conditions for analysis of Pb, Cu, Cd and Cr.

| Analyte | Wavelength (nm) | Read time (s) | Nebulizer Flow (L/min) | Background correction |
|---|---|---|---|---|
| Pb | 405.781 | 3 | 0.75 | Auto |
| Cu | 324.754 | 3 | 0.7 | Auto |
| Cd | 228.802 | 3 | 0.5 | Auto |
| Cr | 425.433 | 3 | 0.9 | Auto |

## IV. QUALITY CONTROL (QC)

General QC required in a routine laboratory were employed throughout the analysis. This includes the analysis of an initial calibration verification solution, a method blank and laboratory control sample. For every 10-sample one method blank were analysed. An ICV solution prepared using a different source was used to verify the integrity of the analytical calibration. The CCV solution measures instrument drift during the sample analysis. These QC samples were digested according to the digestion procedure given in the 'Sample preparation' section. Instrumental limit of detections (LOD) was determined by analysing six blank solutions and applying a factor of 3.14 times the standard deviation of those results. Limit of Quantification (LOQ) was set at 10 times the LOD.

## V. ESTIMATED DAILY INTAKE (EDI)

Potential risks to human health posed by the consumption of contaminated cassava were assessed by calculating the estimated daily intake (EDI) based on average metal concentrations measured at each Junction as follows [1].

$$EDI = \frac{C\ x\ Cr}{BW}$$

Where: C is the average concentration of a heavy metal measured in cassava (mgkg$^{-1}$), *Cr* is the estimated daily cassava flour consumption rate (0.422 kgd$^{-1}$), and BW is the assumed average body weight set at 60 kg for adults [14].

## VI. STATISTICAL ANALYSIS

Results were expressed as the duplicates of mean ± Standard Deviation (SD). The data were analyzed by Microsoft Excel 2019 and SPSS version 20.0 and also bar charts was drawn to illustrate the content of lead and copper in each sample area.

## III. RESULTS AND DISCUSSION

### I. LEAD

Lead is soft, ductile, malleable, has low melting and is resistant to most corrosive agents making it widely employed in industries, agriculture, and domestic uses. It is one of the highly toxic metals that have a great negative effects on the major organs in the body [15]. The levels of lead contaminant at some selected Junctions in Makurdi were studied using cassava chips as indicators and the results presented Table 1, Fig. 2 and Fig. 3. From the result shows that the average concentrations of lead were 4.85 mgkg$^{-1}$, 1.26 mgkg$^{-1}$, 1.51 mgkg$^{-1}$ and 5.18 mgkg$^{-1}$ with estimated daily intake (EDI) of 0.0341 mgkg$^{-1}$d$^{-1}$, 0.0088 mgkg$^{-1}$d$^{-1}$, 0.0106 mgkg$^{-1}$d$^{-1}$ and 0.0364 mgkg$^{-1}$d$^{-1}$ at Balcony Junction, Yina Junction, International Market Junction and Terwase Agbadu Junction respectively. The results were however higher than report of Brown and Milton, [16] and Ogunkunle [17] and safe limits set by World Health Organization (WHO) (0.30 mgkg$^{-1}$) and National Agency for Food and Drugs Administration and Control (NAFDAC) (0.10 mgkg$^{-1}$). Ordinarily, the concentrations at each Junction are expected to increase steadily but this trend was not observed and may be due to uneven distribution of the metals on the surfaces of the cassava chips and irregular rise and fall in the anthropogenic activities at the sampling points.

Table 2 Concentrations (mgkg-1) of Lead (Pb) in Local Cassava Chips

| Sample A (Balcony Junction) | | Sample B (Yina Junction) | | Sample C (International Market Junction) | | Sample D (Terwase Agbadu Junction) | |
|---|---|---|---|---|---|---|---|
| R2 | 0.9971 | R2 | 0.9971 | R2 | 0.9971 | R2 | 0.9971 |
| LOD | 0.000072 | LOD | 0.000072 | LOD | 0.000072 | LOD | 0.000072 |
| LOQ | 0.000239 | LOQ | 0.000239 | LOQ | 0.000239 | LOQ | 0.000239 |
| Control | 0.07±0.00 | Control | 0.07±0.00 | Control | 0.07±0.00 | Control | 0.07±0.00 |
| A 1 | 21.79±0.25 | B 1 | 0.99±0.05 | C 1 | 1.99±0.00 | D 1 | 1.96±0.02 |
| A 2 | 1.25±0.01 | B 2 | 0.64±0.02 | C 2 | 2.16±0.02 | D 2 | 15.86±0.24 |
| A 3 | 1.25±0.03 | B 3 | 1.15±0.04 | C 3 | 3.12±0.03 | D 3 | 0.98±0.03 |
| A 4 | 1.49±0.01 | B 4 | NA | C 4 | 0.82±0.02 | D 4 | 0.43±0.01 |
| A 5 | 1.26±0.04 | B 5 | 2.56±0.00 | C 5 | 1.34±0.02 | D 5 | 13.25±0.11 |
| A 6 | 4.62±0.02 | B 6 | 1.12±0.03 | C 6 | 0.65±0.02 | D 6 | 2.48±0.02 |
| A 7 | 2.31±0.03 | B 7 | 1.07±0.02 | C 7 | 0.49±0.03 | D 7 | 1.28±0.04 |
| WHO | 0.30 | WHO | 0.30 | WHO | 0.30 | WHO | 0.30 |
| NAFDAC | 0.10 | NAFDAC | 0.10 | NAFDAC | 0.10 | NAFDAC | 0.10 |

*Analyses were in triplicates and values recorded as mean ±S.D. **NA: Not Analysed

All samples had lead concentrations higher than the control related to exposure effect to the contaminants. The highest levels of lead were recorded at Balcony Junction on day 1 and 6 and Terwase Agbadu Junction on day 2 and 5 Table 2. The high levels of lead observed especially at Balcony Junction are due to high anthropogenic activities. The anthropogenic activities around Balcony Junction include traffic congestion especially on weekends and evenings as the Junction has an established popular club. There is also traffic lights located at the four-round Balcony Junction where speeding vehicles that do not follow traffic rules have to brake rapidly. Adamiec et al., [12] noted that brakes and tires are subjected to high friction generating a significant amount of heat especially at road Junctions, road bends, traffic lights, near zebra crossing and emergency braking where rapid breaking is required. Adamiec et al., [12] reported that dust samples from brake linings and tires had contamination particularly with significant amounts of Cu, Pb, and Cr.

The highest mean concentration of Pb (5.18 $mgkg^{-1}$) was recorded at Terwase Agbadu Junction as shown in Fig. 2. This area is populated by potent Pb sources like industrial waste from the Rice mills (Grain Reserve with hundreds of large trailers), Coca cola factory and also the motor vehicle garages by the roadside. Iwegbue et al., [18] found out that the cancer risk linked to children ingesting dust around automobile garages exceeded the threshold level of $10^{-6}$ $mgkg^{-1}$. In another experiment on the spatial distribution of heavy metals with varying distances from a busy highway in Bangladesh, Islam et al., [19] showed that the lead concentration at the closest point (0 m from the highway) was high. The researchers attributed this to emissions from vehicles exhausts, smelting, and other manufacturing activities.

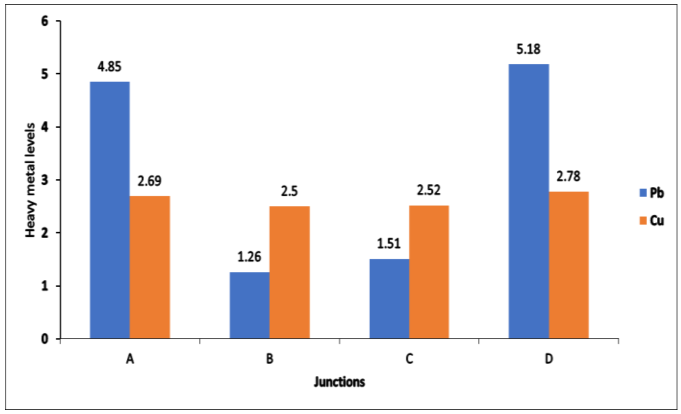


Fig. 2 Mean concentrations of Pb and Cu at selected Junctions in Makurdi

## II. COPPER

Human toxicity from copper is generally rare, but its deficiency can include anaemia, mental retardation, cardiovascular disease, colon cancer and changes in the skeletal system [20]. Cu is the major component of vehicle electronics for example the weight of Cu in car ranged between 15 kg in small car and 28 kg for luxury cars. Copper is also used in system designed to reduce petrol consumption and $CO_2$ emission especially in hybrid and fuel cell vehicles. Copper are in motors, alternators, actuators, and electrical chocks [18]. From the result in Table 3 and Fig. 2, the average concentrations of copper from the sampled cassava chips were 2.69 $mgkg^{-1}$, 2.50 $mgkg^{-1}$, 2.52 $mgkg^{-1}$ and 2.78 $mgkg^{-1}$ for Balcony Junction, Yina Junction, International Market Junction and Terwase Agbadu Junction respectively.

Table 3 Concentrations ($mgkg^{-1}$) of Copper (Cu) in Local Cassava Chips

| Sample A (Balcony Junction) | | Sample B (Yina Junction) | | Sample C (International Market Junction) | | Sample D (Terwase Agbadu Junction) | |
|---|---|---|---|---|---|---|---|
| R2 | 0.9996 | R2 | 0.9996 | R2 | 0.9996 | R2 | 0.9996 |
| LOD | 0.000002 | LOD | 0.000002 | LOD | 0.000002 | LOD | 0.000002 |
| LOQ | 0.000006 | LOQ | 0.000006 | LOQ | 0.000006 | LOQ | 0.000006 |
| Control | 0.03±0.01 | Control | 0.03±0.01 | Control | 0.03±0.01 | Control | 0.03±0.01 |
| A 1 | 4.03±0.01 | B 1 | 3.75±0.01 | C 1 | 2.83±0.00 | D 1 | 2.98±0.01 |
| A 2 | 2.31±0.01 | B 2 | 2.49±0.00 | C 2 | 2.69±0.00 | D 2 | 3.30±0.02 |
| A 3 | 2.76±0.01 | B 3 | 3.26±0.00 | C 3 | 2.99±0.01 | D 3 | 3.04±0.00 |
| A 4 | 2.57±0.00 | B 4 | NA | C 4 | 3.05±0.00 | D 4 | 2.49±0.00 |
| A 5 | 2.52±0.00 | B 5 | 2.01±0.00 | C 5 | 2.88±0.00 | D 5 | 4.44±0.00 |
| A 6 | 2.78±0.01 | B 6 | 1.69±0.00 | C 6 | 2.09±0.00 | D 6 | 1.67±0.00 |
| A 7 | 1.92±0.00 | B 7 | 1.81±0.01 | C 7 | 1.09±0.00 | D 7 | 1.54±0.01 |
| WHO | 40.00 | WHO | 40.00 | WHO | 40.00 | WHO | 40.00 |
| NAFDAC | 40.00 | NAFDAC | 40.00 | NAFDAC | 40.00 | NAFDAC | 40.00 |

*Analyses were in triplicates and values recorded as mean ±S.D. **NA: Not analysed

Terwase Agbadu Junction recorded the highest concentration of Cu 2.78 $mgkg^{-1}$ followed by Balcony Junction with a 2.69 $mgkg^{-1}$ Cu concentration recorded as shown in Table 4. The high Cu concentration at Terwase Agbadu Junction was attributed to the electronic wastes from the motor vehicles garages, workshops and spare parts shops in this area. Gorka et al., [21] reported that concentrations of Cu from a highway in Northern India was high than for Pb and Fe. The researchers noted that the city neighboring this road hosts many automobile garages, electrical shops and motor vehicle yards for heavy duty trucks.

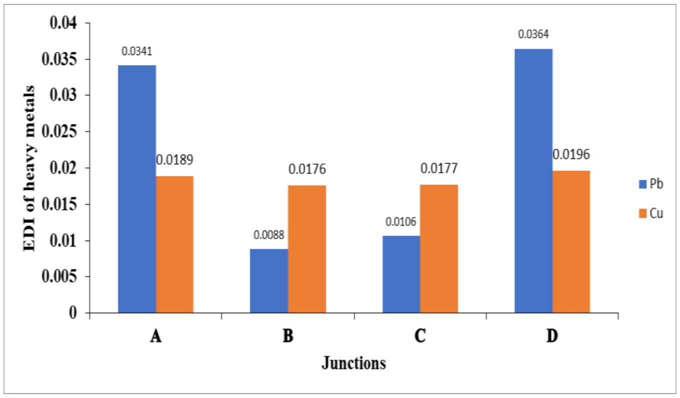


Fig. 3 EDI (mg $kg^{-1}$ $d^{-1}$) of Pb and Cu at selected Junctions in Makurdi.

From the result in Fig. 3 above, the estimated daily intake (EDI) for copper was 0.0189 $mg^{-1}kg^{-1}d^{-1}$, 0.0176 $mg^{-1}kg^{-1}d^{-1}$, 0.0177 $mg^{-1}kg^{-1}d^{-1}$ and 0.0196 $mg^{-1}$ $kg^{-1}d^{-1}$ at Balcony Junction, Yina Junction, International Market Junction and Terwase Agbadu Junction respectively. The highest levels of copper were recorded at Terwase Agbadu Junction on day 5 and Balcony Junction on day 1 (Table 4). The concentrations of copper were also seen to be within permissible limits set by WHO and NAFDAC (40.00 $mg^{-1}kg^{-1}$). Excess copper intake over time can cause anaemia, liver and kidney damages, stomach and intestinal irritation [22]

## III. Cadmium

The levels of cadmium contaminant at some selected Junctions in Makurdi were also studied using cassava chips as an indicator and the results presented Table 4 and Fig. 5. Cadmium is one of the most life-threatening metals from the earth's crust exhibiting high toxicity if ingested through soil, food and water [23]. Cadmium metal is non- essential to animals and leads to onset of cancer and other critical health implications when it leaches into food [24].

Cadmium concentrations in cassava chips assessed from four different locations in Makurdi metropolis recorded maximum value at balcony Junction (0.226 $mgkg^{-1}$) followed by Agbadu Junction (0.204 $mgkg^{-1}$). International market had the third highest concentration (0.076 $mgkg^{-1}$) and lastly, Yina Junction (0.045 $mgkg^{-1}$). The concentrations of cadmium in the cassava chips at Balcony and Terwase Agbadu Junctions were above the permissible limits while those at international market and Yina Junctions within the permissible limit (0.1 $mgkg^{-1}$) according to Nigerian Industrial Standards (NIS).

The high levels of cadmium in the cassava chips at location A and D were attributed to exposure of the cassava chips to vehicular emissions for a long period during open sun drying. The high levels of Cd at Balcony Junction can also be attributed to the wearing of the road since the Junction is situated along a worn-out road characterised by potholes and high traffic density. Cadmium, Mn, and Zn were identified as the most significant pollutants noted in Melbourne, Australia and whose concentrations depended on the traffic features such as the age of the road, number of vehicles passing by and the speed at which the vehicles move [25]. Utilisation of engine oil is a major source of atmospheric Cd contamination since it is used as an antiknock agent [22] contributing significantly to the pollutant concentration at these junctions.

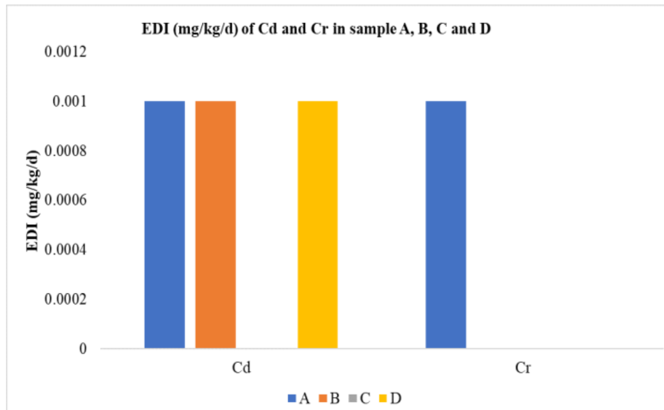


Fig. 4 EDI ($mgkg^{-1}d^{-1}$) of Cd and Cr in sample A, B, C and D

The estimated daily intake was gotten to be 0.001 $mgkg^{-1}d^{-1}$ for samples A, B, and D while that of sample C was 0.000 $mgkg^{-1}d^{-1}$ as shown in Fig. 4. These were all within the limit set by the Agency for Toxic Substances and Disease Registry (0.001 $mgkg^{-1}d^{-1}$). Basri et al., [27] reported that fish sundried in the open had a higher amount of Cd in the muscles. The researchers concluded that the heavy metal concentrations were as a result of deposits from the atmosphere during drying compared to solar-dried fish. The mean Cd concentration analysed from *E. sardella* and most fish dried at the shores of Lake Malawi exceeded the maximum FAO recommended levels with a 0.6mg $kg^{-1}$ [28]. The cadmium levels were attributed to the emissions from boats. The high concentration of cadmium at those locations are harmful to human beings when consumed. Cadmium directly damage nerve cells by inhibiting the release of acetyl choline and activating cholinesterase enzyme that results to a shift in hyperactivity of the nervous systems [29].

Table 4 Concentrations (mgkg$^{-1}$) of Cadmium (Cd) in Local Cassava Chips

| Sample A (Balcony Junction) | | Sample B (Yina Junction) | | Sample C (International Market Junction) | | Sample D (Terwase Agbadu Junction) | |
|---|---|---|---|---|---|---|---|
| R2 | 0.9999 | R2 | 0.9999 | R2 | 0.9999 | R2 | 0.9999 |
| LOD | 0.000003 | LOD | 0.000003 | LOD | 0.000003 | LOD | 0.000003 |
| LOQ | 0.000009 | LOQ | 0.000009 | LOQ | 0.000009 | LOQ | 0.000009 |
| CONTRL | ND | CONTRL | ND | CONTRL | ND | CONTRL | ND |
| A1 | 0.449±0.019 | B1 | ND | C1 | ND | D1 | 0.016±0.010 |
| A2 | ND | B2 | ND | C2 | ND | D2 | 0.537±0.011 |
| A3 | 0.003±0.008 | B3 | ND | C3 | ND | D3 | ND |
| A4 | ND | B4 | NA | C4 | ND | D4 | ND |
| A5 | ND | B5 | 0.025±0.012 | C5 | 0.025±0.012 | D5 | ND |
| A6 | ND | B6 | 0.065±0.014 | C6 | 0.065±0.014 | D6 | 0.060±0.009 |
| A7 | ND | B7 | ND | C7 | ND | D7 | ND |

*Analyses were in triplicates and values recorded as mean ±S.D. **ND: Not detected
***NA: Not analysed

## IV. CHROMIUM

Chromium concentrations recorded maximum concentrations at balcony (0.245 mgkg$^{-1}$) and Agbadu (0.078 mgkg$^{-1}$) Junctions (Table 5). Yina Junctions and international Market Junctions recorded 0.031 mgkg$^{-1}$ and 0.001 mgkg$^{-1}$ respectively. From research, there was no permissible limit found for chromium concentration from either NAFDAC or Standards Organization of Nigeria (SON). The estimated daily intake of sample A was 0.001 mgkg$^{-1}$d$^{-1}$ and 0.000 mgkg$^{-1}$d$^{-1}$ for B, C and D (Fig. 4). Long-term exposure to Cr (III) can harm the kidneys, liver, or lungs. By inhalation, Cr (VI) has been found to be a human carcinogen and to be extremely hazardous to living organisms [30].

The overall result showed a significant difference across the difference in the presence of chromium and cadmium levels in the different cassava samples. No Chromium was detected in the controls since they were isolated and not exposed to vehicular emissions.

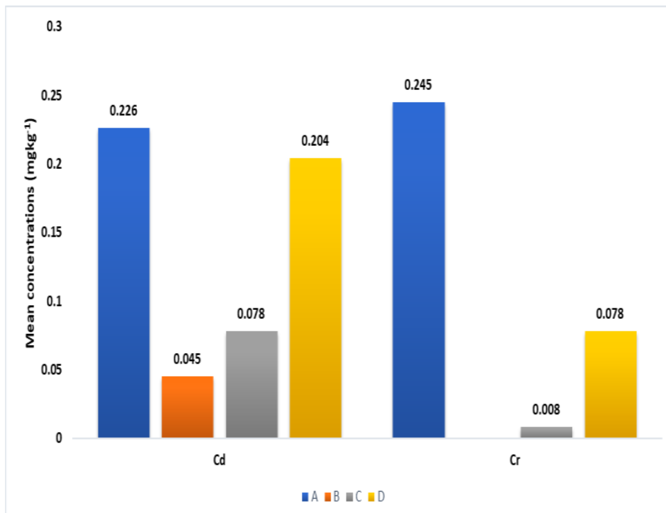


Fig. 5 Mean concentrations (mgkg-1) of Cd and Cr in Sample A, B, C, and D

Table 5 Concentrations (mgkg-1) of Chromium (Cr) in Local Cassava Chips

| Sample A (Balcony Junction) | | Sample B (Yina Junction) | | Sample C (International Market Junction) | | Sample D (Terwase Agbadu Junction) | |
|---|---|---|---|---|---|---|---|
| $R^2$ | 0.9994 | $R^2$ | 0.9994 | $R^2$ | 0.9994 | $R^2$ | 0.9994 |
| LOD | 0.000001 | LOD | 0.000001 | LOD | 0.000001 | LOD | 0.000001 |
| LOQ | 0.000002 | LOQ | 0.000002 | LOQ | 0.000002 | LOQ | 0.000002 |
| CONTRL | ND | CONTRL | ND | CONTRL | ND | CONTRL | ND |
| A1 | 0.278±0.004 | B1 | 0.190±0.002 | C1 | 0.008±0.001 | D1 | ND |
| A2 | ND | B2 | ND | C2 | ND | D2 | 0.190±0.009 |
| A3 | ND | B3 | ND | C3 | ND | D3 | ND |
| A4 | ND | B4 | NA | C4 | ND | D4 | 0.036±0.005 |
| A5 | ND | B5 | ND | C5 | ND | D5 | 0.121±0.003 |
| A6 | 0.213±0.002 | B6 | ND | C6 | ND | D4 | ND |
| A7 | ND | B7 | ND | C7 | ND | D5 | ND |
| WHO | - | - | - | - | - | - | - |

In a majority of the samples chromium and cadmium were not detected, but this may point to untraceable amounts being in them and not exactly their absence. Amarh et al.,[31] reported a mean Cr concentration of 0.211 $mgkg^{-1}$ with a range of 0.113–0.339 $mgkg^{-1}$ in in infant food sold in Wa, Ghana. The researchers noted that there was significant contribution of the contaminant from vehicular emissions.

## IV. CONCLUSION

The presence of environmental pollutants; lead, copper, cadmium, and chromium content in an agrarian city in Nigeria was determined using cassava chips dried at select road Junctions in Makurdi Metropolis as an indicator. The heavy metal concentrations reported provide insight and additional information on vehicular emissions pollution in Benue State Nigeria, food safety hazards associated with consumption of cassava flour from cassava dried on the highways in Makurdi Metropolis, and inform local food regulatory authorities. This research showed that cassava flour from cassava chips dried at four road junctions in Makurdi Metropolis are contaminated with some heavy metals in reference to heavy metals limits set by NAFDAC and WHO but at varying concentrations. The evaluation of the estimated daily intake (EDI) indicated clear unsafe exposure over time through consumption of the cassava floor.

The findings of this research suggests that more attention should be given predominantly to the lead, and cadmium levels to guarantee food safety and to protect the consumers from food that may harm their health. We recommend restrictions on drying cassava products or any other foodstuffs along the roads in Makurdi Metropolis and regulations on vehicular pollutants emissions in the town by the State and Federal Government regulatory firms.

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